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Vitamin C content of cranberries

Paul Dwight Isham
University of Massachusetts Amherst

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By Paul Dwight Isham

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Contents

	Page
Introduction and historical	1
Methods	3
Preparation of materials for feeding	5
Fresh cranberries	6
Boiled cranberry juice	7
Pasteurized cranberry juice	7
Whole cranberry sauce	8
Strained cranberry sauce	9
Cranberry juice cocktail	10
Cranberry jelly	12
Cranberry candy	12
Cranberry film	13
Results of feeding experiments	14
Fresh cranberries - 1930 crop	16
Boiled cranberry juice	18
Pasteurized cranberry juice	19
Fresh cranberries - 1931 crop	20
Effect of storage at 40°F	21
Cranberry sauce	24
"Ten-Minute" cranberry sauce	25
Hot-strained cranberry sauce	26

INTRODUCTION AND HISTORICAL

Extensive investigations have been carried out and reported (9) relative to the production of cranberries, their chemical composition, and the manufacture and properties of cranberry products, but previous to this time, no thorough investigation of the vitamin C in cultivated cranberries has been reported.

Macleod and Booher (8) reported the cranberry as being a poor source of vitamin C. This conclusion is open to criticism because: first, the cranberries had been in storage for at least seven months, and as will be demonstrated below, had undoubtedly lost much of their vitamin C content; and second, the experimental animals did not consume the full quota of fruit plus the basal ration.

Naeslund (10) investigated the vitamin C content of European cranberries and found them to be very weakly antiscorbutic. He estimated the protective portion for guinea pigs to be over 50 cubic centimeters a day. The berries used in this test were, of course, different from those which we know as cranberries. The European

cranberry, Preisselbeere, is Vaccinium vitis idaea, whereas the American cranberry is Vaccinium macrocarpum (16). Vaccinium vitis idaea, in English terminology, is cowberry or red whortleberry. Naeslund fed both the pulp and the juice in order to determine whether or not vitamin C was extracted by pressing the fruit. His results indicated that the antiscorbutic values of the juice and of the tissues were the same.

Laland (7) was unsuccessful in attempts to isolate narcotine, now believed to be the precursor of vitamin C, from mountain cranberries, Vaccinium vitis idaea (16), which he refers to as being "weakly antiscorbutic."

In this laboratory Rice (11) conducted an examination of vitamin C in pasteurized cranberry juice, both cold extracted and heat extracted, sealed hot and vacuum sealed, contemporary with this work, and found no retention of the vitamin C content. He likewise investigated the vitamin C content of dried cranberries as obtained in the market and found them to be devoid of any antiscorbutic potency.

A large number of investigations have been reported relative to the antiscorbutic potency of other

fruits and vegetables and their products, but the results vary so widely depending on the material studied that it would be useless to consider them comparatively with the work reported in this paper.

This investigation was designed to accurately determine the antiscorbutic potency of raw cranberries, and the effect of all methods of manufacture and storage upon this.

Methods

The experimental method used was that of Sherman, La Mer, and Campbell (12). Young guinea pigs, weighing from 300 to 350 grams were fed the basal diet and water ad libitum. This diet is adequate, so far as is known, except for vitamin C, and consists of:

Baked skimmed milk	30 parts
Equal parts bran and rolled oats	59 parts
Butter fat	10 parts
Sodium chloride	1 part
Cod liver oil	1 part

The animals were housed singly in cages with raised bottoms made of 1/4 inch sand screen to allow the droppings to pass through into trays below (See Plate I).

Plate I Photograph of section of cages illustrating type of cage, food and water cups, and trays.

Since the animals disliked cranberries in most forms, it was necessary to force-feed by pipet (See Plate II), each animal being fed six days each week. This was time consuming but not difficult, because most of the animals tolerated the force-feeding very well. The animals were first weighed, then fed, then weighed again. In fact, the feeding was regulated by weight only. In this way, it was absolutely certain that each animal received his share - no more and no less.

Autopsies were performed on all animals at death. If the animals survived the 90 day feeding period, they were chloroformed and the autopsies then performed. The severity of the scurvy lesions was scored according to an arbitrary system proposed by Sherman (12). This numerical score is based on autopsy findings of weakness in the bony system (joints, ribs, jaw, and teeth) and hemorrhages in joints, ribs, muscles and intestines. One, two, or three plus signs are recorded for each of the eight parts examined according to the degree of abnormality found, thus making possible a maximum score of 24. It was noted in this work that hemorrhages of the bladder were practically invariably found in cases of scurvy, but absent in all other instances. This

Plate II Photograph illustrating method used in feeding materials by pipet. The animals, when placed in a bowl on a towel, became more docile.

characteristic lesion, which is not mentioned in any of the literature, was taken into account in scoring the hemorrhages of the intestines. Several of the animals receiving supplemented diets deficient in vitamin C developed an apparent xerophthalmia, but this was not frequent enough to be classed as a characteristic scurvy lesion. Our experiments likewise indicated that much less variation in results occurred when the full 90 day feeding period was used.

Negative controls, which received the basal ration only, invariably died from scurvy in from 23 to 36 days (See Plate III). Their mean survival period was 28 days and their mean scurvy score was 19. Positive controls were also used for comparisons, the animals receiving two grams of grapefruit juice daily (2). These animals more than doubled in weight and showed no evidence of scurvy lesions (See Plate IV).

Over 200 guinea pigs were used in these feeding tests.

Preparation of Materials for Feeding

The cranberries used in the feeding experiments with the 1930 crop were harvested during September and

Plate III Photograph illustrating healthy and scurvied animals. Note apparent stupor, dull unkempt coat, closed eyes and retarded growth of the scurvied animal, as compared with the alert appearance, sleek glossy coat, and excellent physical condition of the healthy animal.

Plate IV Photograph showing scurvy lesions on viscera. Note hemorrhagic blotches (H) on stomach (upper right), bladder (lower right) and intestines (left).

October at the State Cranberry Experiment Station near Wareham, Massachusetts. They were shipped to the College and kept in cold storage at 40°F. until used. Whenever cranberry products were being assayed, raw cranberries of the same lot were tested to determine the actual antiscorbutic potency of the berries used. The two most important commercial varieties, i.e., Early Blacks and Howes were used. The frozen cranberries were kept solidly frozen at 15°F.

The cranberries used in the feeding experiments with the 1931 crop were harvested from the same locality during the corresponding months and treated similarly. Additional freezing experiments were carried out on these in conjunction with the General Seafood Corp. in Gloucester, Mass., and the materials are now being assayed. However, definite conclusions on these cannot be drawn at the time of writing.

Preparation of Fresh Cranberries (Juice)

Since it was found necessary to force-feed by pipet, raw cranberries could not be fed as such. The cold fruit was thoroughly ground in a small food chopper and the juice and finer particles of pulp pressed out.

The small quantity of coarse residue remaining was discarded. Fresh fruit was prepared each day in this manner for feeding. At most, two hours elapsed between the time of preparing the fruit and feeding the animals. Since vitamin C is water soluble, it is believed that this method of preparing the sample is a fair one. Obviously, if any error results from this method, it can be due only to a loss of part of the vitamin C. Other results prove, however, that cold straining of cranberries is not harmful, although hot straining is very detrimental to the vitamin C content of the fruit. Naeslund (10) found the juice and pulp to be equally rich in vitamin C.

Preparation of Boiled Cranberry Juice

Raw cranberry juice, obtained as described above, was heated to boiling in an uncovered kettle, and boiled vigorously for two minutes. This was fed both unsweetened and sweetened.

Preparation of Pasteurized Cranberry Juice

Both sweetened and unsweetened cranberry juice were prepared and pasteurized. The juice was obtained by grinding and pressing the fruit. That to be pasteurized

unsweetened was heated to 160°F, filled into #1 cans, sealed, and pasteurized at 160°F. for 20 minutes. The cans were then immediately cooled in cold water and stored in the refrigerator at 33°F. That to be pasteurized sweetened was first made up to 50 per cent soluble solids by refractometer by adding sugar, and then treated similarly to the unsweetened juice.

One can was used for two day's feeding, the opened cans being stored in the refrigerator at 33°F. and the surface of the liquid being coated with paraffin.

Preparation of Whole Cranberry Sauce

Whole cranberry sauce was prepared according to the widely used "Ten Minute" Cranberry Sauce (15) recipe of the American Cranberry Exchange. The recipe calls for one pound of cranberries, two cups of water, and one and one-half to two cups of sugar. The sugar and water are boiled together for five minutes, then the cranberries are added and boiled without stirring until the skins pop open. This usually requires about five minutes. This material was sealed hot in small jars and immediately cooled. Investigations on canned foods (4 and 5) have shown that practically no deterioration of

the vitamin C content occurs in the can even over a period of several years. All sauce was kept in the refrigerator at 33°F., and no jar was used for feeding after being open 24 hours. The surface of the material in the opened jars was kept covered with paraffin. Just prior to feeding, the sauce was pressed through a fine screen to allow its being administered by pipet. This process is the one referred to as cold pulping or cold straining in this paper.

It was brought to our attention that cranberry sauce is often prepared in the home by cooking cranberries in water and then adding the sugar. Whole sauce was therefore prepared in this manner and treated as was the "Ten Minute" cranberry sauce.

Commercially prepared whole cranberry sauce was also examined for its vitamin C content. This material was manufactured by the Cranberry Canners Inc. at South Hanson, Mass., according to a method practically identical to that specified for "Ten Minute" cranberry sauce.

Preparation of Strained Cranberry Sauce

The strained cranberry sauce fed was prepared

in several ways. In each case, however, the berries were pulped while at boiling or near boiling temperatures without any special precautions being taken for preventing oxidation. Strained "Ten Minute" cranberry sauce (15) was prepared and sealed in small jars immediately. Other strained sauce was prepared in small amounts according to commercial practice. The cranberries were boiled for two or three minutes in water, pulped while hot to remove seeds and skins, the sugar added, and the mixture concentrated in a jelly kettle to a jelly test (216-218°F. or 43 per cent sugar by refractometer). The hot liquid sauce was filled into cans and hermetically sealed without further heat treatment. As an average, one pound of cranberries will yield 2.6 pounds of sauce. Regular commercially packed strained sauce was likewise tested, that manufactured by the Cranberry Canners Inc. (both regular and vacuum sealed), and by the Hills Brothers Company, New York City was used.

Preparation of Cranberry Juice Cocktail

Cranberry juice cocktail was prepared according to the recipe of the American Cranberry Exchange (15). The recipe calls for one quart of cranberries, one quart

of water, and two-thirds cups of granulated sugar. The cranberries are cooked in the water until all the skins pop open. They are next strained through a cheese cloth bag, the juice brought to boiling, sugar added, and the whole mass boiled 2 minutes. It is then filled into sterilized small jars, sealed, and immediately cooled. A new jar was used each day for feeding and all were stored in the refrigerator at 33°F.

In an experiment designed to avoid destruction of the vitamin C content of the berries during the preparation of the cocktail, the following modifications were used: the cranberries were ground previous to the cooking, and the cooking period was shortened; one part of this cooked mass was immediately strained and pressed, the rest was placed in the refrigerator until cold, then strained and pressed. The rest of the procedure was the same as is called for in the American Cranberry Exchange's recipe.

Commercially prepared cranberry juice cocktail was likewise assayed. This material was manufactured by the Cranberry Canners Inc., South Hanson, Mass. Their method of preparation consists of grinding the fruit, cooking with water until soft, adding a pulp filter mass,

centrifuging, making up the filtrate to a volume representing two parts water to one of fruit, adding sugar to 15° Brix, heating to 180°F., and immediately filling into sterilized containers and sealing. One container was used for two feedings, being resealed and kept in the refrigerator at 33°F. between feedings.

Preparation of Cranberry Jelly

Cranberry jelly was prepared according to the recipe of the American Cranberry Exchange (15). This calls for eight pounds of cranberries, twelve cups of water, and two and one half pounds of sugar. The cranberries are cooked in the water until soft, and the juice strained off through a jelly bag. The juice is measured and heated to boiling, one cup of sugar added for each two cups of juice and stirred in until dissolved, and the whole boiled briskly for five minutes. It is then poured into glasses and covered with paraffin. Small glasses were used, and a new one taken for each feeding.

Preparation of Cranberry Candy

The sugar content of cranberry candy as such was too high to allow feeding in amounts sufficient to

afford protection to the animals. Therefore, the cranberry material as it is mixed into the candy was obtained and used for feeding tests. This material was nothing other than finely chopped cranberries. It was stored, sealed in large jars, in the refrigerator at 33°F. Just prior to feeding, a suitable quantity was pressed through a fine screen while still cold, and this material used for feeding.

Preparation of Cranberry Film

The cranberry film used in this feeding experiment was prepared by Sardik Inc., New York City. The cranberries were boiled in a small amount of water until thoroughly softened (two to three minutes) then pulped hot, and immediately dried on rotating steam drying-drums. The film was packed in glass jars. One ounce of the film was equivalent to approximately 12 ounces of raw fruit (14).

This material was prepared for feeding by mixing with water in definite concentrations. In this form, the desired amounts could be accurately administered by pipet.

Results of Feeding Experiments

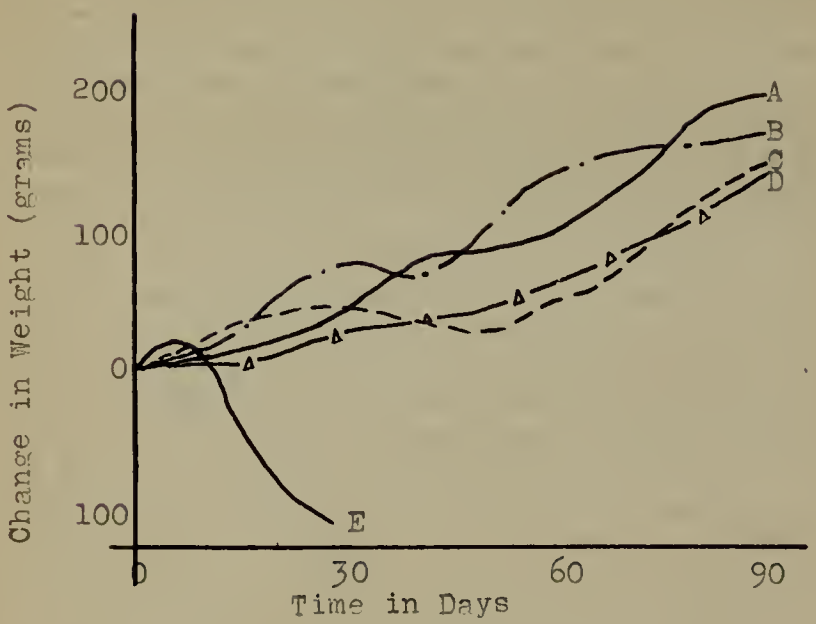
The data obtained are condensed in Tables I to V and representative graphs are presented to explain the results more clearly (See figures I to VIII).

TABLE I VITAMIN C CONTENT OF CRANBERRIES

Form of Cranberry	No. of Guinea Pigs	Quantity Fed Daily grams	Gain in Weight Average days	Survival Period Average days	Scurvy Score Average
1930 Crop					
Raw juice, Early Blacks	5	10	153	90	0
" " " "	5	5	134	90	0
" " " "	2	3	199	90	2
Raw juice, Howes	3	4	123	90	0
" " "	3	2	4.5	90	7
" " "	3	1	-58	42	12
Raw juice, Howes; 9 mos. in regular storage at 40°F.	3	10	176	90	2
Raw juice, Howes; 9 mos. in storage at 15°F.	3	10	-25	90	8
Raw juice, Early Blacks; 9 mos. in storage at 15°F.	3	10	22	90	12
Juice, Howes; boiled 2 minutes	3	8	191.5	90	0
" " " "	3	4	192	90	0
" " " "	3	4+ 5 g. sugar	188	90	0
Juice, Howes; pasteurized 20 minutes at 160°F.	5	4	-102	38	15
Juice, Howes, Sweetened; pasteurized 20 minutes at 160°F.	5	8	-169	49	10
1931 Crop					
Raw juice, Early Blacks	3	4	165	90	1
Raw juice, Howes; 4 to 7 mos. storage at 40°F.	2	5	130	90	6
" " " " "	2	3	-35	87	13

Figure I

Vitamin C Content of Fresh Cranberries (Juice)



(A) 4 grams of Early Blacks - 1931 Crop - Score 1

(B) 3 grams of Early Blacks - 1930 Crop - Score 2

(C) 5 grams of Early Blacks - 1930 Crop - Score 0

(D) 2 grams of Grapefruit Juice - Score 0

(E) Basal ration only - Score 19

Fresh Cranberries (Juice) 1930 Crop

The data obtained on fresh cranberries are given in Table I and Figures I and II.

The cranberries were fresh in that they had not been cooked. They were, of course, a storage product. These results indicate that the protective portion was slightly over three grams of Early Blacks per day.

The animals receiving three grams made even better growth than those receiving the larger amounts, but showed very slight indications of scurvy. The fruit used had been in cold storage at 40°F. from one to four months. The better growth of the animals on the lower level was characteristic of all experiments where the animals received cranberries. Apparently some constituent of the berries is unfavorable to perfect health and growth of the animals.

Later experiments indicated that the protective portion of Howes variety corresponded with that of the Early Blacks. Four grams gave fair growth and entirely protected from scurvy. These berries had been in storage from three to six months and probably had lost a small portion of their vitamin C potency.

From the other results, it is apparent that

after this point there is a rapid decrease in the vitamin C potency of the cranberries. This seems to correlate with the physical condition of the berries which show more rapid deterioration over this period. After 8 to 11 months in storage at 40°F., 10 grams were required to promote growth, and even this increased amount did not fully protect from scurvy. Judging from the scurvy score, the protective portion would probably be between 11 and 12 grams. This represents a loss of approximately 70 per cent of the vitamin C content.

The results obtained on cranberries in freezing storage at approximately 15°F. in ventilated boxes after the same period indicate even greater losses in vitamin C potency. The explanation of this is not apparent at present. The loss might be due to insufficiently low storage temperature, or may occur during and after thawing the berries (1). The more complete investigation of cranberries in freezing storage now in progress may throw more light upon this. The results indicate, moreover, that the Early Black variety loses more of its vitamin C content than the Howes does. Definite values for the protective portions were not obtained, but the indications are that considerably more than 10 grams a

day would be required in each case.

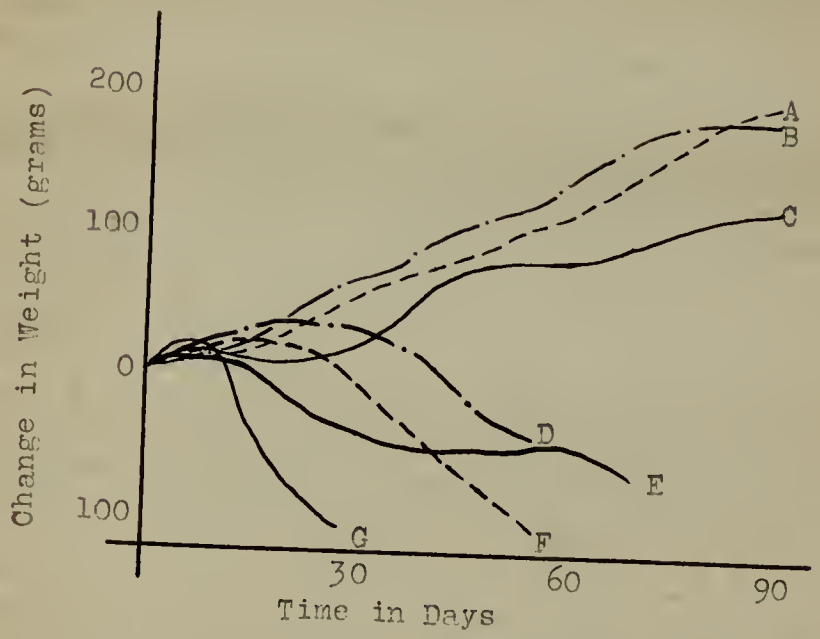
Boiled Cranberry Juice

Rapid boiling in air for short periods (two minutes) apparently has no destructive action on the vitamin C content of the juice. At least, if any destruction occurs, it is not in proportion to the concentrating effect, since four grams of the boiled juice is apparently more potent than a like amount of the untreated. Better growth was maintained throughout the 90 day experimental period, and no indications of scurvy were revealed by the autopsies.

Since many of the animals receiving cranberry sauce or other materials having a high sugar content energetically resisted the feeding and seemed to be unable to digest or utilize such large amounts of sugar, the question arose as to the possibility of this affecting our results. Hence, one group of animals was fed four grams per animal of the boiled juice plus five grams of sugar daily. These animals made practically the same growth as those receiving four grams of boiled juice without sugar, and showed no scurvy symptoms. Strangely enough however, these animals did not resist feeding.

Figure II

Effect of Boiling and Pasteurization on Vitamin C Content of Cranberry Juice



(A) 4 grams of Howes - Boiled 2 minutes - Score 0

(B) 4 grams of Howes - Boiled 2 minutes, plus 5 grams of sugar - Score 0

(C) 4 grams of Howes - Raw - Score 0

(D) 8 grams of Howes - Sweetened and Pasteurized - Score 10

(E) 1 gram of Howes - Raw - Score 12

(F) 4 grams of Howes - Pasteurized - Score 15

(G) Basal ration only - Score 19

Hence, it would seem that the active dislike for certain of the materials by individual animals was the cause of our difficulties, and not the high sugar content alone.

Pasteurized Cranberry Juice

Pasteurization at 160°F. for 20 minutes apparently destroys much of the vitamin C potency of cranberry juice when no special precautions are taken to prevent oxidation. Four grams of the unsweetened juice after pasteurization gave less protection than one gram of the raw juice. The animals survived four days longer on the average, but showed greater weight losses and had somewhat higher scurvy scores, an average of 15 as compared to 12. This would indicate a loss of over 75 per cent of the vitamin C potency by this pasteurization.

Animals receiving sweetened juice after a similar period of pasteurization gave evidence of slightly better protection. Their average survival period was 11 days longer and their average scurvy score was only 10. However, the eight grams fed was slightly more than 50 per cent cranberry by weight. Raw cranberry juice gives a refractometer reading of 4.5 to 6.5 per cent soluble solids, and since sugar was added to give a reading of

50 per cent soluble solids, the amount of cranberry fed was nearer five grams than four. This would seem to explain the slightly better protection obtained. From these results, it seems logical to assume that added sugar does not prevent any of the destruction of vitamin C during pasteurization.

Rice (11), in a repetition of the above experiment in our laboratory, obtained the same results. He also found that even when the juice was vacuum sealed previous to pasteurization, the vitamin C destruction occurred just the same.

Similar results were obtained by experiments carried out at the Glass Container Laboratory (6) on tomato juice. It was found necessary to vacuumize the juice, and then vacuum seal it prior to pasteurization in order to retain the vitamin C content.

Fresh Cranberries (Juice) - 1931 Crop

The results obtained on feeding experiments using cranberries of the 1931 crop indicate that the fruit was not so potent in vitamin C as was the 1930 crop. The protective portion of Early Blacks was found to be very slightly over four grams a day as compared to

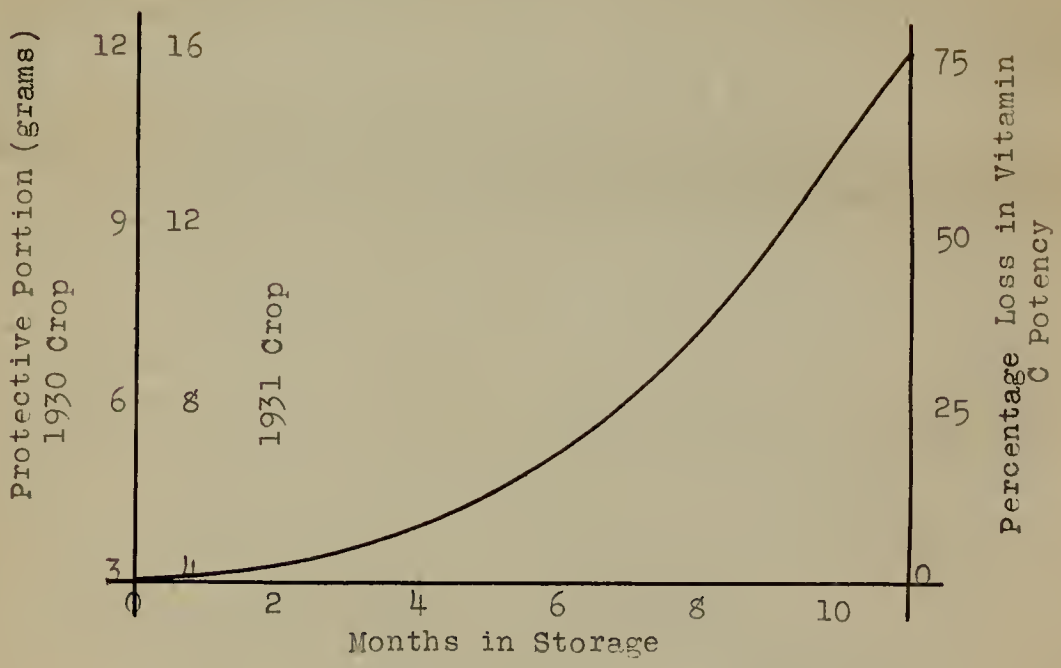
the protective portion of slightly over three grams a day for the 1930 crop. Apparently then, the 1931 crop is only 75 to 80 per cent as potent in vitamin C as the 1930 crop. This same relationship of potency was noted throughout the feeding experiments on cranberry products. Cranberry growers (3) considered the berries of the 1931 crop to be of inferior quality, indicating some correlation between the quality of the berries and their vitamin C content.

Experiments feeding Howes after four to seven months in storage at 40°F. indicate that they, too, were less potent in vitamin C in 1931. Animals receiving five grams a day, although making fair growth, showed definite scurvy lesions, having an average scurvy score of six.

Effect of Storage at 40°F.

The above results, along with those obtained on the 1930 crop give definite data on the relative potency of raw cranberries in storage at 40°F. throughout 11 months in such storage. Figure III represents graphically the percentage loss in antiscorbutic potency over the 11 month period. It is apparent that only a

Figure III



Effect of Storage at 40° F. on the Vitamin C Content of Cranberries

very slight decrease in potency occurs up to about five months. After this time, however, the amount necessary to afford complete protection increases more and more rapidly until approximately 12 grams are required to fully protect after 10 months. Since the cranberry crop is practically all consumed within four months after harvesting, this loss in vitamin C potency in long storage probably has little practical significance.

The results of Macleod and Booher (8) were obtained by feeding cranberries after 7 to 11 months in storage, and the berries used probably were very deficient in vitamin C; and since their highest feeding level was five grams, it is not strange that the animals received hardly any protection.

TABLE II VITAMIN C CONTENT OF CRANBERRY SAUCE

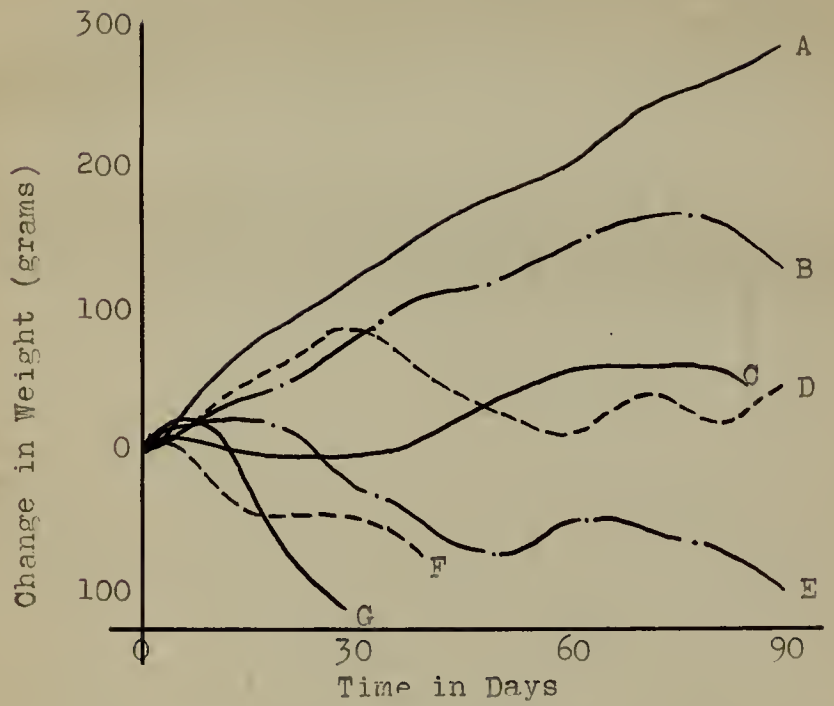
Form of Cranberry	No. of Guinea Pigs	Quantity Fed Daily grams	Gain in Weight Average grams	Survival Period Average days	Scurvy Score Average
1930 Crop					
Whole "Ten Minute" cranberry sauce without sugar	3	14	279	90	0
	4	7	82	90	2
Whole "Ten Minute" cranberry sauce	4	20	42	90	2(?)
" " " "	4	10	132	90	5
Hot strained "Ten Minute" cranberry sauce without sugar	3	8	-49	52	9
Hot strained "Ten Minute" cranberry sauce	3	20	39	83	10
" " "	3	15	-92	33	8
" " "	3	8	-134	38	10
*Strained cranberry sauce	5	20	-70	25	11
" " "	5	10	-164	38	18
" " "	5	8	-62	57	17
1931 Crop					
Whole "Ten Minute" cranberry sauce	3	10	35	90	6
** Whole cranberry sauce	2	10	-99	90	3

*Blanched three minutes in boiling water, pulped hot, and concentrated with sugar to jelly test (216°F)

**Same proportions as "Ten Minute" cranberry sauce, but the sugar added after cooking.

Figure IV

Vitamin C Content of Cranberry Sauce



(A) 14 grams Whole "Ten-Minute" cranberry sauce without sugar - 1930 crop - Score 0

(B) 10 grams Whole "Ten-Minute" cranberry sauce - 1930 crop - score 5

(C) 20 grams Hot strained "Ten Minute" cranberry sauce - 1930 crop - score 10.

(D) 10 grams Whole "Ten Minute" cranberry sauce - 1931 crop - score 6

(E) 10 grams Whole cranberry sauce - sugar added last - 1931 crop - score 3

(F) 20 grams of Hot-strained cranberry sauce - 1930 crop - score 11

(G) Basal ration only - score 19

Cranberry Sauce

Since by far the largest quantities of cranberries consumed are in the form of cranberry sauce, a more thorough investigation of this food was carried out than of any of the other cranberry products. The data obtained on cranberry sauces prepared in our own laboratory are given in Table II and Figure IV.

The first experiments were made on strained cranberry sauce. Even 20 grams daily of this material afforded no protection and was so large an amount that it shortened the survival period to 25 days. (Animals receiving much over 10 grams of sauces did not consume the customary amount of their basal ration, and when not protected, often died even before the controls).

Nearly all animals receiving cranberry to which sugar had been added, strenuously resisted feeding. Hence the next experiment was designed to further note the effect of the high sugar diet as well as to evaluate differently prepared sauces and possible causes of the vitamin C destruction noted above.

"Ten Minute" Cranberry Sauce

"Ten Minute" cranberry sauce, American Cranberry Exchange formula, was prepared both with and without sugar; part of each lot was strained immediately after boiling, and part retained as whole berries. Seven grams of the whole berries nearly protected and gave only slightly subnormal growth. This amount corresponds to four grams of fresh cranberry. Fourteen grams gave excellent growth and fully protected. In the light of the other results, however, this was far above the protective portion which is estimated at nine grams. This corresponds to five and one half grams of cranberry. This material, of course, had to be forced through a fine screen just previous to feeding - cold pulped. Since raw cranberries had to be fed in practically this same quantity at the same time to afford protection, it is apparent that cold pulping has little effect on the vitamin C potency of the material.

Ten grams of the "Ten Minute" cranberry sauce as whole berries gave good growth but hardly protected. According to the scurvy scores of the animals, the protective portion should be around 12 grams. This represents approximately 80 per cent retention. Of the four animals

on 20 grams of the same material, there was considerable variation, two animals having scurvy scores of 0, and two having scores of four each. It seems hardly correct, considering this whole group, to place the protective portion over 20 grams. The poor growth on the larger amount is typical of all animals receiving large amounts of sauce, and was probably influenced by several conditions; the continued high sugar diet; the continued utilization of such large amounts of acid; and the strenuous resistance of the animals to feeding throughout the experimental period.

Hot Strained Cranberry Sauce

None of the animals receiving sauces which were strained hot survived the 90 day experimental period, and all had comparatively high scurvy scores. Those receiving 8 grams of the material containing no sugar lived slightly longer and did not show such high losses as those receiving cranberries with sugar. Their scurvy scores indicate, however, that they were receiving no better protection. Of those receiving cranberries with sugar, the animals being fed 20 gram portions made very slight growth, but none survived the experimental period

and the average scurvy score was 10. This would indicate that the protective portion was well over 20 grams. However, they did show much better protection than those receiving 20 grams in the first experiment. Since the destruction of vitamin C in the hot strained sauce is due to accelerated oxidation at high temperatures, this difference is to be expected. In the first instance, a boiling period both preceded and followed the mixing with air; whereas in the latter instance, although the cranberries were at boiling temperature when strained, they were then immediately cooled.

Cranberry Sauce from 1931 Crop

Another group of animals were fed 10 grams of whole "Ten Minute" cranberry sauce prepared from the 1931 crop. These animals all survived the 90 day feeding period and made slight gains, but showed some symptoms of scurvy. The results, however, were practically as would be expected considering that lower vitamin C content of the cranberries that year, for although their gain in weight was much less than that of the animals on the same amount the previous year (35 grams as compared to 132 grams), their scurvy score was only one higher

(six as compared to five). Considering that the raw fruit of the 1931 crop was only 75 to 80 per cent as potent in vitamin C as that harvested in 1930, these results further substantiate the estimation of 80 per cent retention of vitamin C in the preparation of cranberry sauce according to the "Ten Minute" cranberry sauce recipe.

The results obtained by feeding 10 grams of cranberry sauce made in the same proportions as the above but with adding the sugar after the cooking, indicate that there is no increased destruction by this method. Although the animals lost weight, they survived the full 30 days and had an average scurvy score of but 3. Since the berries used had been stored several months, they had lost some of their vitamin C potency. In view of these results, it is to be concluded that there is approximately a 75 per cent retention when cranberry sauce is prepared in this manner.

Commercially Prepared Cranberry Sauce

The data obtained on the vitamin C content of commercially packed cranberry sauce are given in Table I t and Figure V.

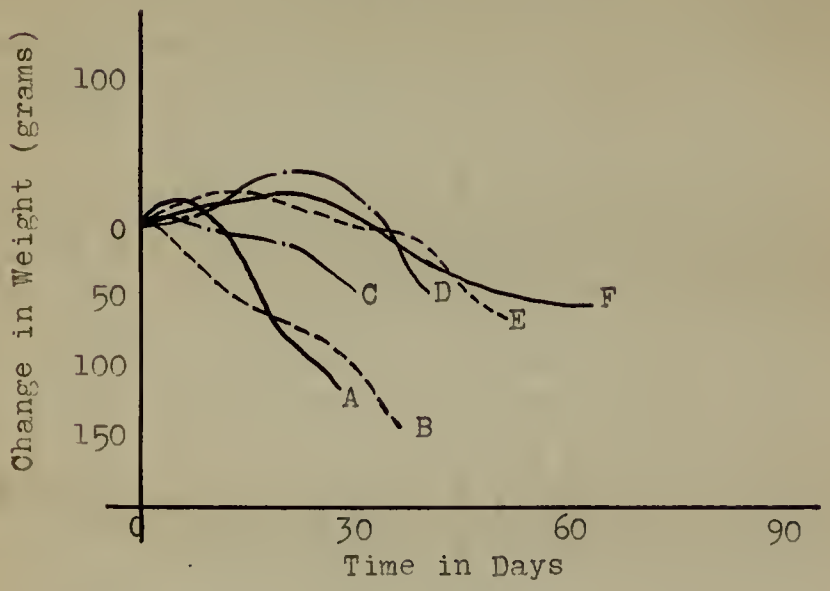
TABLE III VITAMIN C CONTENT OF COMMERCIAL CANNED CRANBERRY SAUCE

Kind of sauce	No. of Guinea Pigs	Quantity Fed Daily grams	Gain in Weight Average grams	Survival Period Average days	Scurvy Score Average
1930 Crop					
M. S. C. Strained	5	26	-146	31	16
Sauce	5	13	-148	31	15
Ocean Spray	2	20	- 50	29	12
Strained Sauce	2	10	- 61	33	13
Ocean Spray	3	20	- 58	38	14
Whole Sauce	3	10	- 23	35	16
Ocean Spray Strained	2	20	- 58	50	17
Sauce (vacuum packed)	2	10	- 52	52	15
Dromedary Strained	2	20	- 73	37	17
Sauce	2	10	- 48	33	16
1931 Crop					
Ocean Spray Whole Sauce	3	12	- 60	65	5

Experiments in which animals were fed canned strained cranberry sauce made in our own laboratory according to commercial practices, but in comparatively

Figure V

Vitamin C Content of Commercial Canned Cranberry Sauce



(A) Basal ration only - score 19

(B) 20 grams M.S.C. strained sauce - score 16

(C) 20 grams "Ocean Spray" strained sauce - score 12

(D) 20 grams "Ocean Spray" whole sauce - 1930 crop - score 14

(E) 20 grams "Ocean Spray" strained sauce - vacuum packed - score 17

(F) 12 grams "Ocean Spray" whole sauce - 1931 crop - score 5

small amounts, indicated complete destruction of the vitamin C content of the cranberries. All the animals on both levels, 13 and 26 grams daily, died as soon as the controls, had practically as high scurvy scores, and even greater losses in weight.

However, it would seem quite possible that in working with large volumes, as is done in regular commercial production, the contact with air would be so minimized as to reduce the destruction of the vitamin C content considerably. Samples taken from regular production were gladly furnished by the manufacturers in order that we might investigate such a possibility. None of the animals receiving these materials outlived the controls, except those receiving the vacuum packed sauce, and even these died in about 50 days and had high scurvy scores.

The animals receiving the "Ocean Spray Whole Cranberry Sauce" made of the 1930 crop showed no better protection than those receiving strained sauce, even though this material was prepared in practically the same manner as the "Ten Minute" cranberry sauce. Their whole sauce made from berries of the 1931 crop immediately after harvesting did afford some protection, The animals

survived 65 days, and their deaths were probably due to pneumonia rather than to scurvy, since their average scurvy score indicated at autopsy was but five. Judging from results obtained by feeding different amounts of raw cranberry, this would indicate a retention of 40 to 50 per cent of the vitamin C potency. This latter material was a thin, fluid sauce instead of the customary firm jellied product.

A possible explanation of the destruction of the vitamin C content of the cranberries during the commercial process for the manufacture of whole sauce is that the time period during which the temperature is either boiling or near boiling is much longer than that in the case of small laboratory batches. Likewise, in the various transfers of the material from one container to another, there is always considerable exposure to and mixing with air.

In the case of the strained sauces we have even longer periods at high temperatures, the same mixing and exposures to air, and the added process of pulping the fruit to remove skins and seeds. It is probable that the last is the one which completes the destruction. Results on our own sauces indicated that hot straining,

even when there was no further heat treatment, caused practically complete destruction of the vitamin C content.

TABLE IV VITAMIN C CONTENT OF CRANBERRY JUICE COCKTAIL

Form of Cranberry	No. of Guinea Pigs	Quantity Fed Daily grams	Gain in Weight Average grams	Survival Period Average days	Scurvy Score Average
Cranberry juice cocktail (Exchange's recipe)	3	10	-165	46	15
	3	5	-162	33	15
Cranberry juice cocktail (Exchange's recipe with modifications) Hot pressed	2	10	-134	33	15
Cold pressed	2	10	- 80	32	18
Cranberry juice cocktail, Ocean Spray (1930)	3	20	- 91	40	15
	3	10	- 85	37	13
Ocean Spray (1931)	3	15	-131	26	12
	2	10	-165	29	16

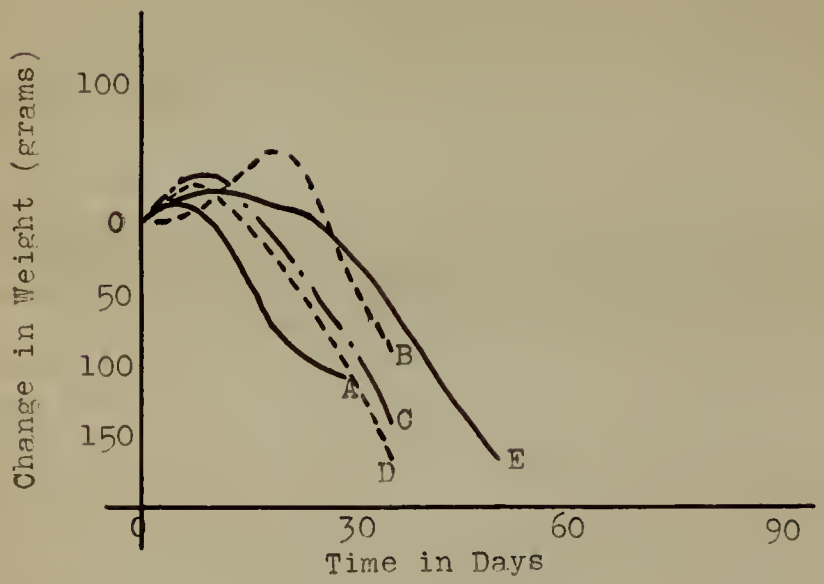
Cranberry Juice Cocktail

The data obtained on the vitamin C content of cranberry juice cocktail are given in Table IV and Figure VI.

All the experiments on cranberry juice cocktail prepared according to the American Cranberry

Figure VI

Vitamin C Content of Cranberry Juice Cocktail



(A) Basal ration only - score 19

(B) 10 grams of "Ocean Spray" cranberry juice cocktail - 1930 crop - score 13

(C) 10 grams of modified Exchange's recipe (Hot pressed) - score 15

(D) 10 grams of "Ocean Spray" cranberry juice cocktail - 1931 crop - score 16

(E) 10 grams of cranberry juice cocktail - Exhange's recipe - score 15.

Exchange's recipe were made using berries of the 1931 crop. The results indicate practically complete destruction of the vitamin C content during the preparation of the cocktail. Animals receiving 10 grams did survive the controls by a few days, but had high scurvy scores and decreased over 50 per cent in body weight. This might indicate a small trace of remaining vitamin C, but no more than a very small trace.

These results seemed inconsistent with the results obtained on the "Ten Minute" cranberry sauce, since the cooking period for preparing cocktail is no longer than that for sauce, and it would seem as though there were but a small chance for oxidation during the pressing. It was decided to modify the procedure in such a way as to cut down the cooking period, to avoid the possible destruction due to the presence of hot gases under pressure before the berries burst, and to minimize oxidation during pressing by first cooling the cooked mass. These attempts were unsuccessful, however, since 10 grams of both the cold and hot pressed juices afforded no protection whatsoever. The animals died as soon as the controls, and all had high scurvy scores.

Commercially prepared cranberry juice cocktail was likewise investigated. The samples were taken from regular production at the Cranberry Canners Inc. plant at South Hanson, Mass. The first lot obtained was prepared from the 1930 crop and fed in 20 and 10 gram amounts daily. Neither level proved sufficient to afford any protection to the animals. Another lot prepared from the 1931 crop within a month after the berries were harvested was tested. Even 15 grams of this, (the highest portion fed) afforded no protection.

Hence, both home and commercially prepared cranberry juice cocktail contain practically no vitamin C.

Other Cranberry Products

The remaining data obtained on the vitamin C content of other cranberry products are given in Table V and Figure VII.

TABLE V VITAMIN C CONTENT OF OTHER CRANBERRY PRODUCTS

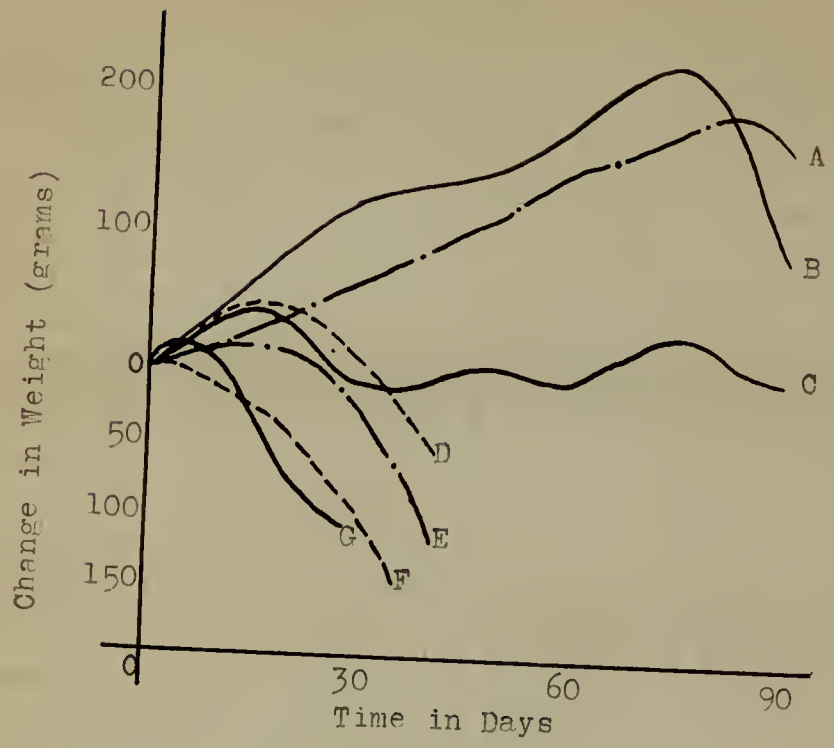
Cranberry Product	No. of Guinea Pigs	Quantity Fed Daily grams	Gain in Weight Average grams	Survival Period Average days	Scurvy Score Average
Cranberry jelly	3	12	-156	40	12
Cranberry Candy Filling, 1930 Crop	2	10	- 80	36	16
	2	5	-103	47	18
1931 Crop	2	6	-157	35	14
	2	3	-122	36	15
Cranberry Film	2	2	164	90	0
	2	1	3	90	4

Cranberry Jelly

The preparation of cranberry jelly is very similar to that of cranberry juice cocktail, except for the use of larger amounts of sugar and longer cooking periods. Hence, the jelly was expected to be devoid of any vitamin C. Consequently only one group of animals was run, these being fed 12 grams of the jelly each day. All died at approximately the same time as the controls

Figure VII

Vitamin C Content of Other Cranberry Products



(A) 2 grams of cranberry film - score 0

(B) 5 grams of Howes - 1931 crop - 6 months storage - score 6

(C) 1 gram of cranberry film - score 4

(D) 10 grams of cranberry candy filling - 1930 crop - score 16

(E) 12 grams of cranberry jelly - score 12

(F) 6 grams of cranberry candy filling - 1931 crop - score 14

(G) Basal ration only - score 19

and had high scurvy scores, indicating complete destruction of the vitamin C.

Cranberry Candy

It was first attempted to feed cranberry candy (a chocolate coated fruit fondant) as such, but the sugar content was so high the animals could not digest it. Feeding tests were carried out, therefore, on the cranberry pulp as it is prepared for addition to the candy. Experiments using the pulp prepared from the 1930 crop of cranberries after about 9 to 10 months in storage indicated that it was entirely lacking in vitamin C. Further feeding tests were made on the material prepared from berries of the 1931 crop soon after harvesting. This was likewise found to be devoid of all vitamin C.

Since this material receives no heat treatment, it is quite possible that it could be so handled as to conserve its vitamin C content. At present, however, it becomes well mixed with air during grinding, and is allowed to remain in that condition. Complete destruction may well be expected under such conditions.

Cranberry Film

This material is a new cranberry product not yet on the market. It was tested for the sake of completeness of this investigation.

One gram of the film just maintained the original body weight of the animals and did not fully protect them from scurvy. Two grams fully protected and gave good growth. Judging from the scurvy score of the animals receiving one gram, the protective portion should be about 1.2 gram of the film per day.

Raw cranberries of the same lot as that used in preparation of the film were tested at the same time. Approximately five and one half grams of raw cranberry were required to give full protection to the animals. This indicates a 40 per cent retention of the vitamin C content of cranberries in the present method used for the preparation of this cranberry film. With precautions against oxidation, and less time consuming practices, it is quite possible that this retention can be greatly increased.

A tomato product manufactured in exactly the same manner, but requiring only one minute for the whole process, has been tested and found to have lost

none of its original vitamin C content (14).

Dried Cranberries

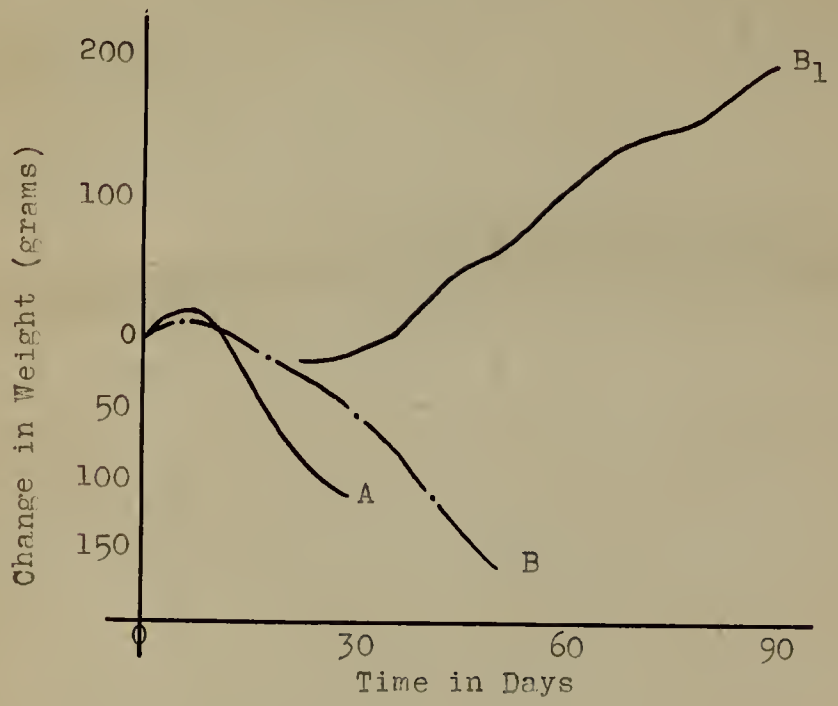
Rice (11), working in this laboratory, found that dried cranberries, as prepared commercially, contained no vitamin C. This is probably because of the long exposure to heat which is required. Even though the temperatures used are quite low, the time of exposure is sufficiently long, especially since there is no exclusion of the oxygen, to destroy all the vitamin C content.

Curative Tests

Several animals' diets were changed from hot strained sauce to raw cranberry juice after the animals were apparently hopelessly afflicted with scurvy. Rapid recoveries almost invariably resulted. The typical recoveries of two of the animals are shown graphically in Figure VIII. After a few days on the raw cranberry juice, they lost their lameness and stupor, and started to gain; at the end of the experimental period they showed no fresh scurvy lesions, and were in excellent physical condition.

Figure VIII

Curative Tests



(A) Basal ration only - score 19

(B) 20 grams of Hot strained cranberry sauce - score 11

(B_1) Two animals changed to 10 grams of raw cranberry juice - score 0

These curative tests furnish additional proof of the relatively high vitamin C content of raw cranberries.

SUMMARY

The antiscorbutic values of two varieties of American cultivated cranberries, vaccinium macrocarpum, as raw fruit and as manufactured cranberry products, were investigated using the method of Sherman, La Mer, and Campbell, and results obtained as follows:

1. A hemorrhagic condition of the bladder was found to be a characteristic scurvy lesion, although this was not indicated in literature.
2. Large amounts of cranberry fed daily over extended periods are unfavorable to good growth and health of guinea pigs.
3. Approximately three grams daily of the raw fruit of the 1930 crop after four months in storage, Howes and Early Black varieties, were found to fully protect a 300 gram guinea pig against scurvy. No difference in the vitamin C potency was found in the two varieties studied.
4. Approximately four grams daily of the raw fruit of the 1931 crop after three months in storage was necessary to fully protect, indicating a potency of only 75 per cent that of the 1930 crop. Some

correlation is indicated between the quality of the berries and the vitamin C content.

5. The antiscorbutic potency of raw cranberries decreases in storage at 40°F. This vitamin C decrease is negligible up to about five months, after which time it increases much more rapidly. A corresponding physical deterioration was noted.

6. After nine months in freezing storage at 15°F. cranberries were found to have lost nearly all their antiscorbutic potency. Further experiments are under way to investigate the cause of this destruction.

7. Rapid boiling in air for two minutes had no measurable effect on the antiscorbutic potency of raw cranberry juice.

8. Addition of sugar to cranberries does not affect the susceptibility of guinea pigs to scurvy. It does seem to cause the animals to dislike the material and resist feeding, which results in poorer growth.

9. Pasteurization of cold extracted cranberry juice at 160°F for 20 mimutes destroys nearly all the vitamin C content. The addition of sugar previous

to pasteurization does not prevent any of this destruction.

10. Cold pulping of cranberry sauce causes no apparent destruction of its antiscorbutic potency.

11. Whole cranberry sauce made according to the "Ten Minute" cranberry sauce recipe of the American Cranberry Exchange retains approximately 75 per cent of the antiscorbutic potency of the fresh fruit.

12. Whole cranberry sauce made adding the sugar last retains approximately 75 per cent of the antiscorbutic potency of the fresh fruit.

13. Hot straining of cooked cranberries destroys practically all of the antiscorbutic potency of the fruit.

14. Commercially prepared whole cranberry sauces vary, retaining from 0 to 40 or 50 per cent of the vitamin C.

15. Commercially prepared strained cranberry sauces contain very little vitamin C. This is believed to be due to long heating periods and mixing with air.

16. Cranberry juice cocktail prepared according to the American Cranberry Exchange's recipe retains

practically none of the antiscorbutic potency of the fruit. Grinding previous to cooking, and cold pressing do not aid in such retention.

17. Commercially prepared cranberry juice cocktail contains substantially no vitamin C.

18. Cranberry jelly as prepared by the American Cranberry Exchange's recipe retains very little of the antiscorbutic potency of the fruit.

19. Cranberry pulp as used in the preparation of cranberry candy contains practically no vitamin C.

20. Cranberry film, a drum-dried product, as prepared commercially, retains approximately 40 per cent of the vitamin C content of the cranberries.

BIBLIOGRAPHY

1. Bracewell, M. F., Kidd, F., West, C., and Zilva S. S., "The Antiscorbutic Potency of Apples II." Biochem. J. 25, No. 1, 138-42 (1931).

2. Bracewell, M. E., and Zilva, S. S., "Vitamin C in Orange and Grapefruit." Biochem. J. 25, No. 4, 1081 (1931).

3. Cheney, A. U. Personal communications. (1931-1932).

4. Delf, E. M., "The Influence of Storage on the Antiscurvy Value of Fruits and Vegetable Juices." Biochem J. 19, 141-52 (1925).

5. Eddy, W. H., Kohman, E. F., and Halliday, N. "Vitamins in Canned Foods VII." Ind. Eng. Chem. 21, 347 (1929).

6. Hicks, C. G. "Research Survey Reveals Answers to Packing and Bottling Problems." Glass Container 10, No. 4, 8-9, 22-30 (1931).

7. Laland, P., "Experiments on the Isolation of Narcotine from Different Vegetables and Milk." Z. physiol. Chem. 204, 112-14 (1932).

8. Macleod, G. and Booher, L., "The Antiscorbutic Vitamin Content of Some Preserved Foods." J. Home Econ. 22, 588-93 (1930).

9. Mass. Agr. Expt. Sta. Publications on Cranberries, Amherst, Mass.

10. Naeslund, C., "Studies on the Vitamin C Content of Wild Cranberries." Acta. Med. Scand. 76, 425-36 (1931).

11. Rice, C. C., Thesis for M. S. degree, Mass. State College. (1932).

12. Sherman, H. C., La Mer, V. K., and Campbell, H. L., "The Quantitative Determination of the Anti-scorbutic Vitamin (Vitamin C)." J. Am. Chem. Soc. 44, 165-75 (1922).

13. Sherman, H. C., and Smith, S. L., "The Vitamins"

Chem. Catalog Co., New York (1931).

14. Serdik, Inc., Personal communications, April, 1932.

15. "Tasty Ways to Serve the Tonic Fruit." American Cranberry Exchange, New York, 1931.

16. Webel, A., "A German-English Technical and Scientific Dictionary." E. P. Dutton and Co., New York, (1930).

Approved by:

Carl R. Fellers

Leon A. Bradley

Fred W. Morrell

Committee on Thesis

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